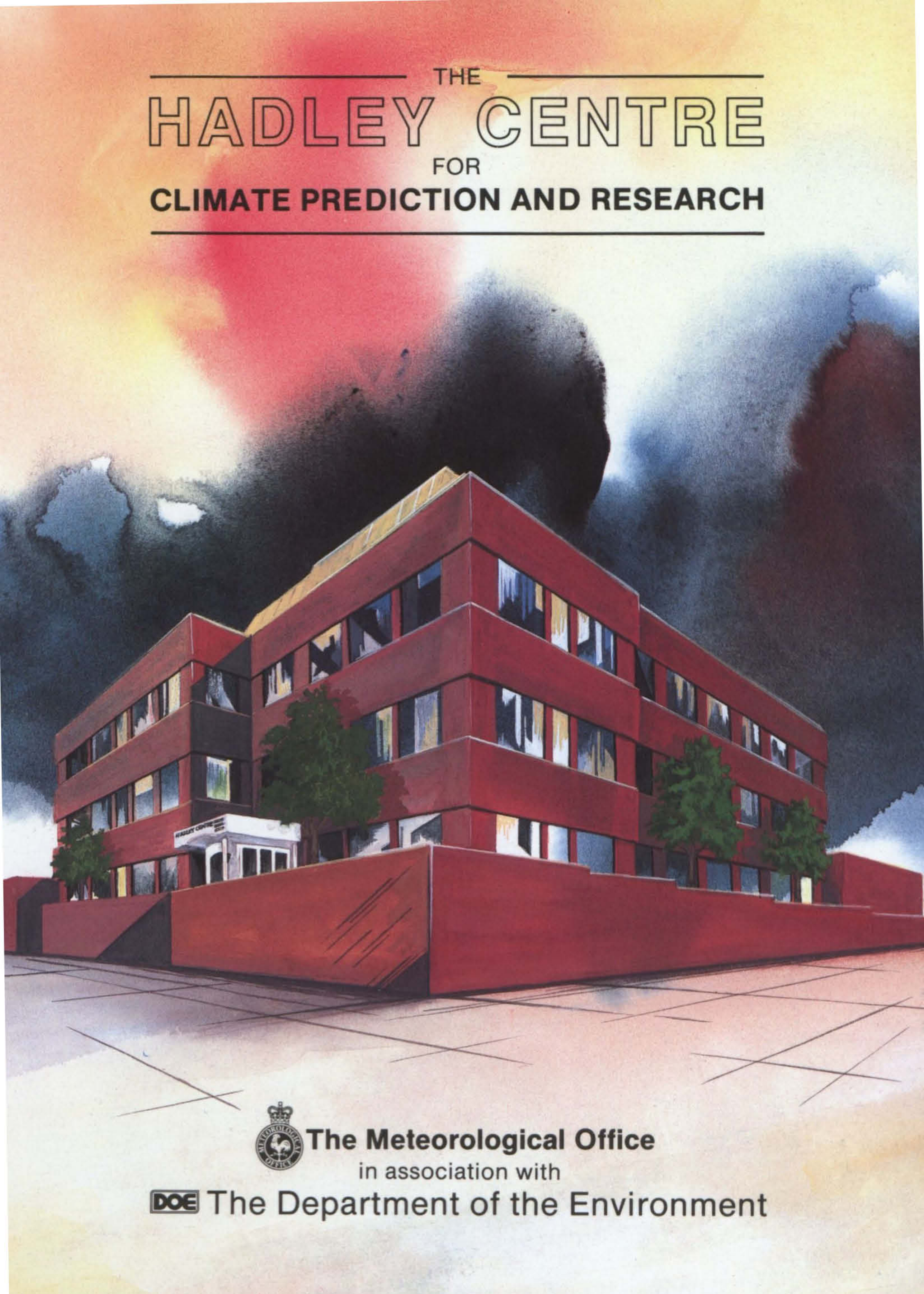
THE HADLEY CENTRE FOR CLIMATE PREDICTION AND RESEARCH



The Meteorological Office
in association with
DOE The Department of the Environment

HADLEY CENTRE
FOR CLIMATE PREDICTION AND RESEARCH

Man's activities are increasing the concentrations of the so-called 'greenhouse gases' in the earth's atmosphere. There are fears of a consequent global warming, local climate changes and sea-level rise that might have significant impacts on human societies. However, there is still considerable scientific uncertainty regarding the nature, magnitude and timing of such changes.

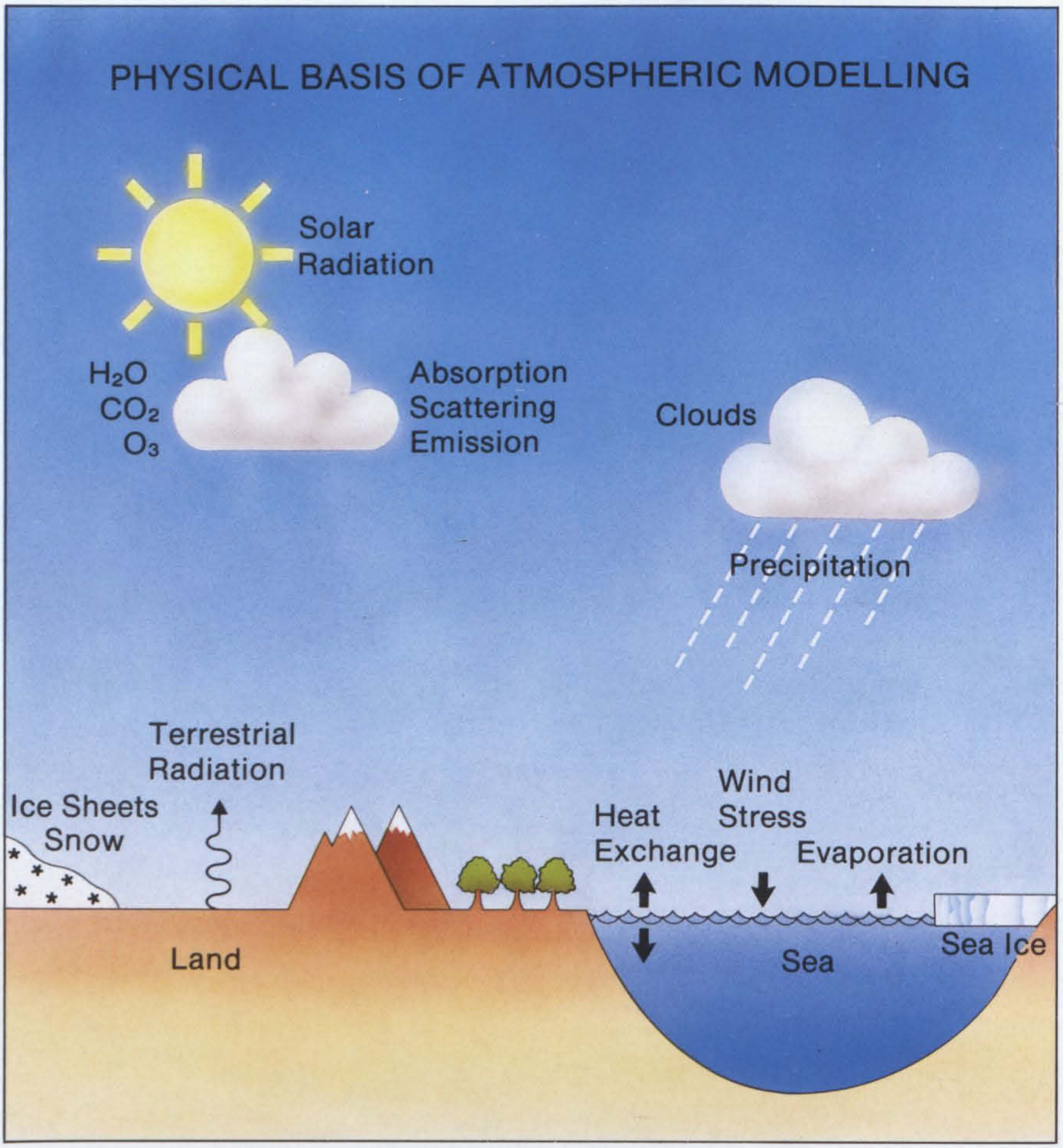
The Hadley Centre for Climate Prediction and Research has been established to increase scientific understanding of the climate system and to reduce the uncertainties surrounding the prediction of climate change. The Centre brings together the considerable scientific expertise in climate modelling and monitoring built up over many years within the Meteorological Office, and combines it with the Department of the Environment's Climate Prediction Programme. Through this Programme the Department of the Environment provides the resources neded, including additional staff and a dedicated supercomputer, to develop as rapidly as possible the climate predictions needed to underpin national and international policy decisions.

1. Climate change

The climate system

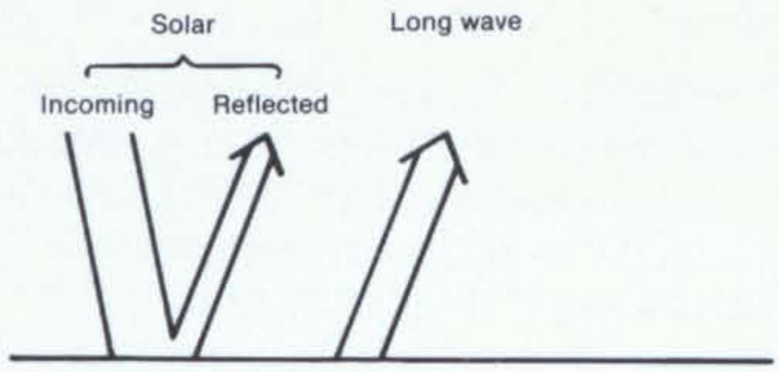
In recent years, climate and the potential for global climate change have come into the public eye and much current interest and awareness have been generated about the impacts of man-made pollutants on the climate system. The ozone hole provided the clearest demonstration so far that changes in concentrations of trace gases can lead to severe and lasting consequences for the atmosphere.

A combination of careful analysis of observational records and experiments with mathematical models of the climate system provides the essential means for the study of the complex interplay of the various processes important to the climate system and for the prediction of climate change. In the atmosphere, the processes affecting climate include the interactions and feedbacks between clouds and radiation, land surface and boundary-layer processes and the exchange of properties between air and sea. The oceans are also important for climate, in particular due to their large heat capacity and the feedbacks which can occur due to changing sea ice extents and altered ocean current systems.

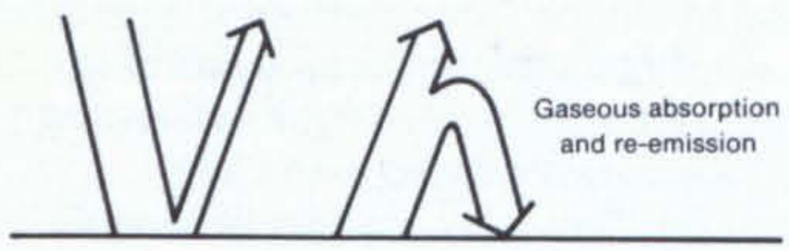


The greenhouse effect

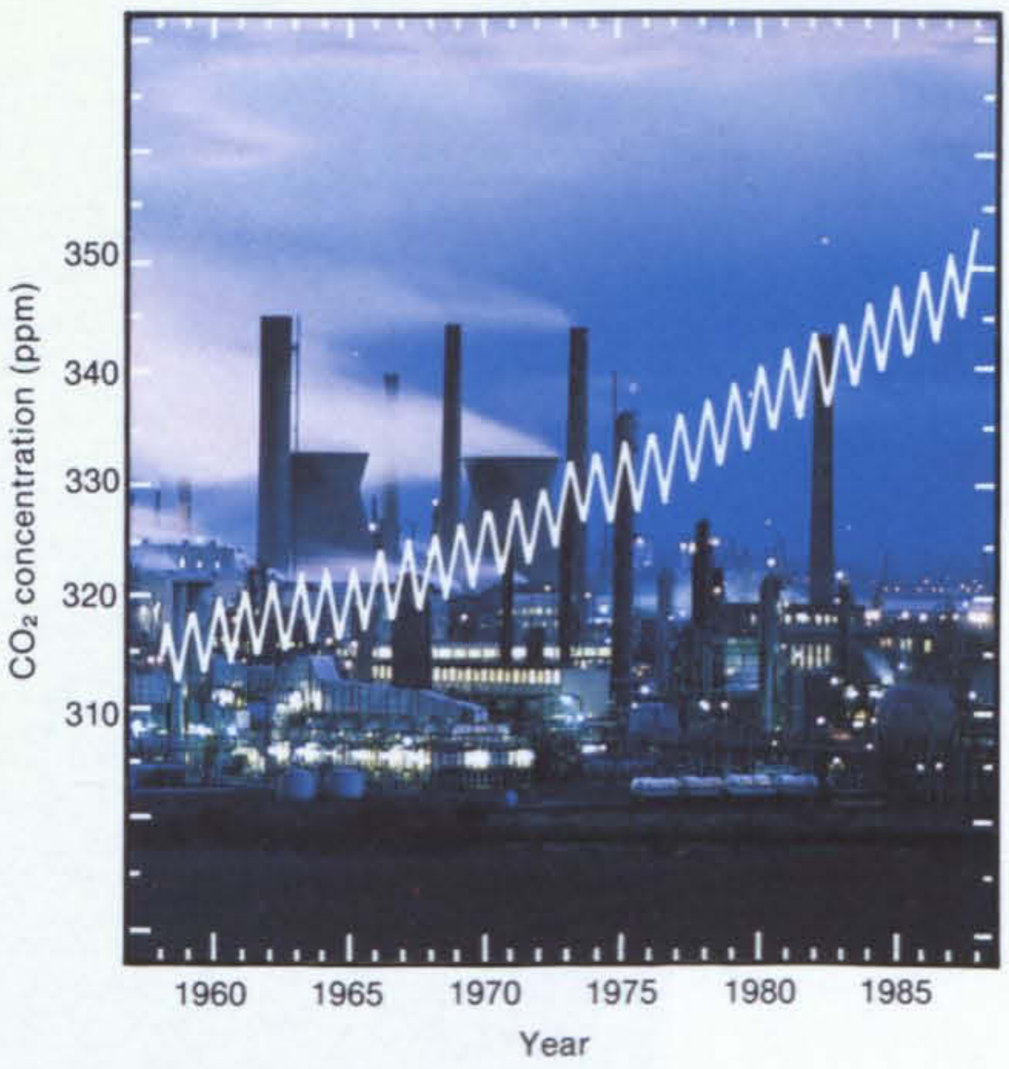
Carbon dioxide (CO_2), water vapour, methane and certain other so-called greenhouse gases in the atmosphere act like a 'one-way blanket', allowing solar radiation to reach the earth's surface but reducing the radiation emitted back to space. Without this blanket, the mean temperature near the surface would be an inhospitable −20 °C; with it, we enjoy a pleasant climate which governs the present pattern of our lives.



(a) No atmosphere (cold surface)



(b) With atmosphere (warm surface)



Man's activities:

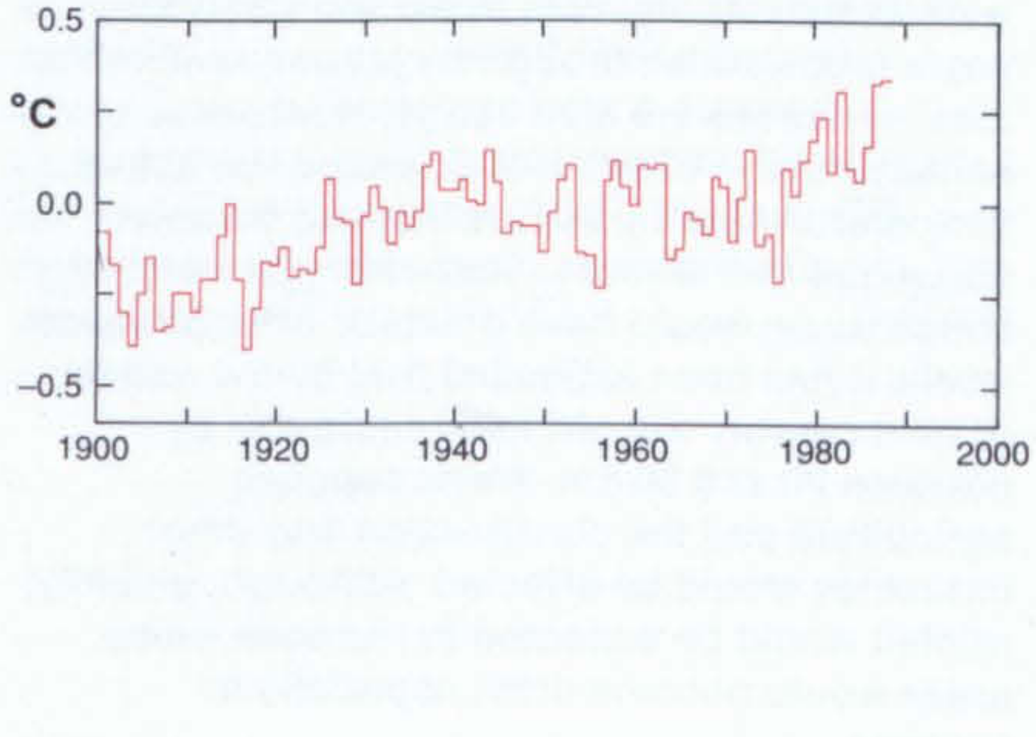
- burning fossil fuels in power stations, homes, cars, etc.
- clearing forests
- intensive agriculture increasing methane and nitrous oxide
- use of chlorofluorocarbons (CFCs) in aerosols, refrigeration and air-conditioning,

are increasing the atmospheric concentrations of greenhouse gases (both those occurring naturally and new, man-made ones). This is threatening to disturb the natural heat balance and change the climate, raising temperatures and causing floods in some regions and droughts in others, with attendant population stress and economic disruption.

Is the temperature rising?

Scientists believe that the observed increase of about 0.5 °C in the globally averaged surface temperature from 1900 to 1989 (with 1988 being the warmest year since global records began) is likely to be, at least in part, related to increases in the amount of greenhouse gases, particularly CO_2. The rate of increase of these gases in the atmosphere is accelerating. Climate variability on shorter time-scales, however, gives rise to temperature fluctuations well in excess of the trend and, consequently, firm predictions into the future are difficult to make. Regional changes may be much larger than the global average and some areas may, paradoxically, experience cooling.

Global surface air temperature relative to 1950–79 average



2. Climate Research

Modelling

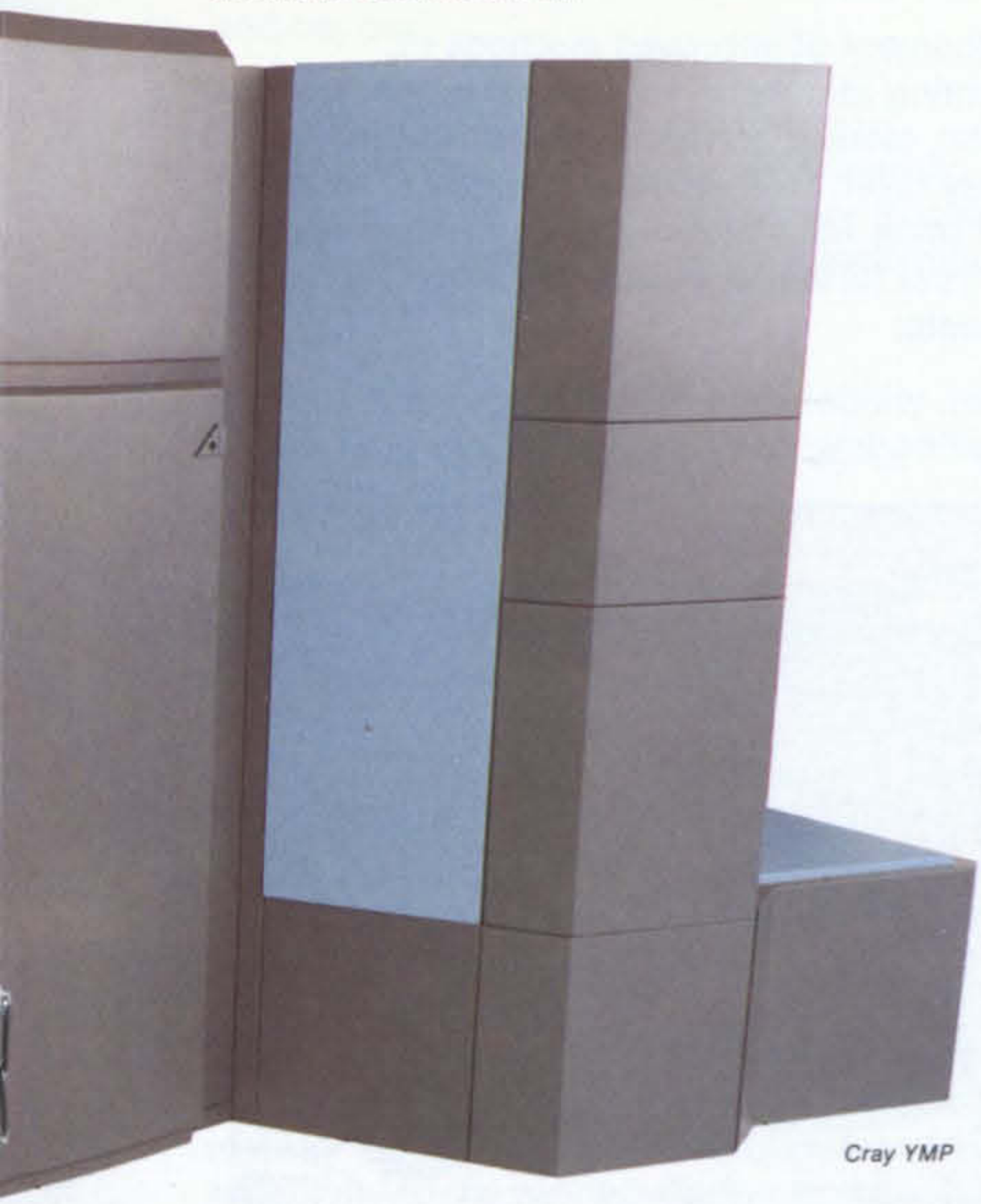
The relationship between greenhouse-gas concentrations and atmospheric temperature is complex because of the large thermal inertia of the oceans (which slows down the rate of warming), because of the sensitivity to temperature of sea-ice (which has a high reflectivity and provides an insulating barrier between the oceans and the atmosphere) and because of clouds (which reflect a large fraction of the sun's radiation and trap some of the outgoing radiation — also their nature and amount are expected to change with temperature). The only practicable way of studying these effects is by using comprehensive computer models of the atmosphere and oceans to predict how the climate could change due to increasing greenhouse gases. A numerical model of the atmosphere, ocean, sea-ice and land-surface system developed within the Meteorological Office provides a state-of-the-art facility for studying the physics of climate change; it will be run on a Cray YMP computer — the most powerful supercomputer currently available.

Results so far indicate that the observed increases in greenhouse gases since 1850 should have been responsible for a rise of global temperature (in the absence of other climatic influences) of about 0.8 °C. Even if drastic steps were taken now to hold greenhouse gas emissions at their present levels, the temperature would still be expected to rise by a further amount between 0.5 and 1.5 °C by 2040. If all greenhouse gases continue to increase in amount at their present rates then, by the year 2040, it is predicted that the world will be committed to an eventual warming within the range 1.5 to 4.5 °C; this would be warmer than at any time in the last 125,000 years (substantial, though as yet unquantifiable, local variations are also likely). However, because of the effect of the oceans, the actual temperature rise by 2040 is likely to be only about half this amount. Such changes in temperature would have dramatic effects on sea levels; it has been estimated that by the middle of next century the sea level could rise by between 20 and 50 cm. Water supplies, agriculture and the construction and other industries would be affected. Although, globally, rainfall would be expected to increase, some areas would become drier, especially in summer.

Meteosat

Observations

Climate is naturally variable, so to confirm that there are real global trends and also to check model performance, accurate observations are needed of rainfall, temperature and other variables. Regional changes as well as global ones need to be considered as they may yield 'fingerprints' of man-made climatic change. Satellites, with their global observing capability, provide the only means of obtaining many of the observations required. Knowledge of the variations of climate in the more distant past is important too — they provide a framework against which any changes in the more recent past and those of the future can be compared. There will also be a need for reliable global observations of changes of the land surface due to deforestation, shifts in patterns of agriculture or the spread of deserts, which may be due to climatic change or may themselves cause it.



Cray YMP

C-130 Hercules

Experiments

Some aspects of the greenhouse effect, such as its effect on radiative properties of clouds and on the oceans, will require specialized measurements by aircraft, ships and satellites. Computer models will not give reliable predictions if the processes they are supposed to describe are represented incorrectly. There is an urgent need to collect and interpret data fundamental to processes which impact on climate change. What will happen to the liquid water content of clouds in a warmer world? Will a change from ice cloud to water cloud lead to an increase in cloudiness? These and other questions can be tackled with a planned programme of cloud measurements by aircraft for which the Meteorological Office's C-130 Hercules flying laboratory is specifically equipped.

3. Hadley Centre for Climate Prediction and Research

Objectives

At the beginning of 1990, the Meteorological Office, in association with the Department of the Environment, set up the Hadley Centre for Climate Prediction and Research within a new building close to the Headquarters of the Meteorological Office in Bracknell. The Hadley Centre brings together the climate research activities of the Meteorological Office and a new programme of climate-change prediction funded by the Department of the Environment. The Centre aims to enhance significantly research on the physical basis of climate and to ensure the maximum use of the results of climate research, both from the United Kingdom and abroad, in preparing predictions of global and regional climate change throughout the next century. The Centre provides a focus for national research on climate-change prediction and a major point of contact with other international centres and programmes. The predictions of the Centre underpin national and international policy on the 'greenhouse effect'.

The particular objectives of the Centre are:

- To sustain a 'Centre of Excellence' for climate research and prediction which will serve as a focus for fundamental studies on the climate problem, drawing on the expertise of scientists from a wide range of disciplines.

- To provide a foundation for the next phase of work after the Intergovernmental Panel on Climate Change presents its interim report in autumn 1990.

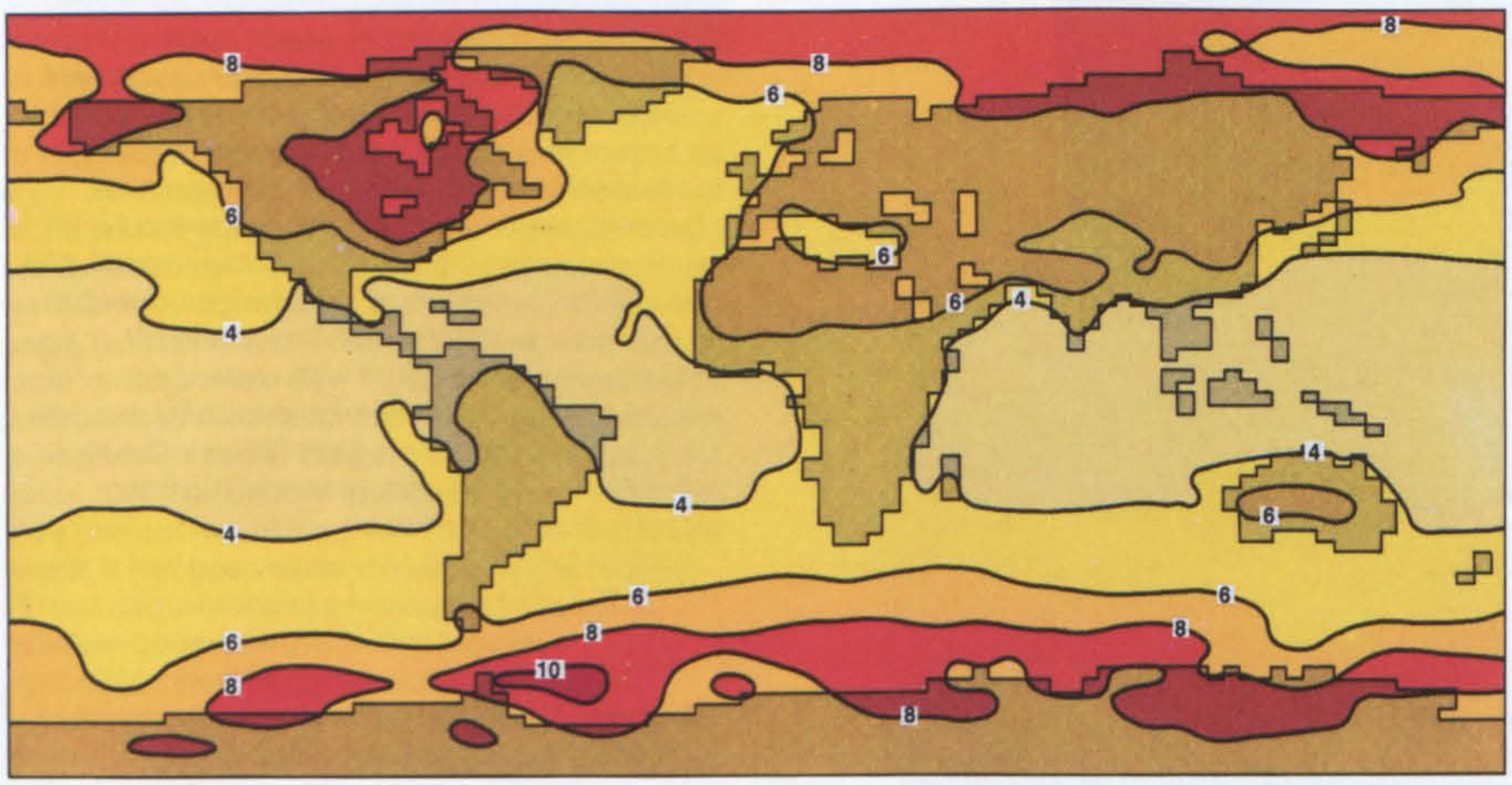
- To make improved predictions of climate over the next 100 years, including the rate of onset of climate change and its regional distribution.

- To play a major role in spreading information and education about climate-change issues world-wide by providing a focus for scientists abroad, especially those from developing countries, to contribute knowledge from their own area of the world to model development.

Work plan

Specific research projects to be undertaken at the Centre over the next few years include:

- development of improved methods of representing atmospheric physical processes (radiation, clouds, convection, atmospheric boundary layer, land-surface processes, effects of mountains, etc.) within climate models using results from further experimental studies where appropriate;



Simulated annual mean equilibrium warming due to doubling carbon dioxide concentrations.
Estimates of the global mean warming range from 2 °C to 5 °C. This diagram represents the upper end of the range.

- development of models of the global and the tropical oceans and their interactions with the atmosphere;

- modelling the formation, transport and decay of sea-ice and the accretion and melting of land ice;

- investigation of the physical basis of climate and its sensitivity to change;

- diagnosis of climate variability from the observational records and the identification of 'fingerprints' of climate change;

- modelling and diagnostic studies of the dynamics and chemistry of the middle atmosphere;

- development of methods of extended-range forecasting for a few weeks to a season ahead, and beyond;

- refining the global coupled ocean–atmosphere model to have a significantly improved spatial resolution in order to predict the evolution and variability of climate over the next 100 years;

- predicting regional climate variability using an even higher-resolution model embedded within the global model;

- providing models to enable investigations of the carbon cycle and sea-level change, and the climatic impacts of deforestation and desertification;

- analysing observations from *in situ* and space-borne instrumentation to provide a climate observational database for validating models and detecting climate change; and

- intercomparing model predictions with those of other internationally renowned Centres to identify the causes of discrepancies and their sensitivity to the representation of different processes, and to establish the level of confidence in the predictions.

The Centre will draw on expertise at other institutions and universities in carrying out some of the research detailed above.

Management and facilities

The Director of the Hadley Centre is Dr David Carson who returned to the Meteorological Office on 1 January 1990 at the end of 3 years' secondment to the Natural Environment Research Council where he was its first Programme Director of Atmospheric Sciences. At the request of the Department of the Environment, the post of Research Co-ordinator was created to expedite the incorporation of results from other relevant programmes into models at the Hadley Centre, and to expand links with organizations and institutes in the United Kingdom and elsewhere, with international programmes (particularly those of the World Climate Research Programme and the Commission for the European Communities Framework Programme) and with the private sector.

The core of the Hadley Centre was formed from staff of two existing Meteorological Office Branches: the Synoptic Climatology Branch and the Dynamical Climatology Branch. These number about 60 scientific and support staff. The Department of the Environment Programme has provided an additional 25 posts, including some Research Fellows on short-term contracts. The Centre also seeks to host visiting scientists from the universities and research institutes in this country and abroad. A supercomputer dedicated to climate-prediction work is also provided for by the DOE Programme. This is essential in order to carry out the proposed research programme on a sufficiently short time-scale to provide a useful input for policy-makers.

Joint research opportunities

The climate problem is multi-faceted and interdisciplinary in nature. The Hadley Centre itself could not possibly hope to encompass all research aspects of the problem; it will concentrate on the tasks for which it has the most expertise, namely the design, application and interpretation of climate models, and the analysis of climate observations. An important component of the Department of the Environment support for the Centre is the provision of funding for co-operative research with scientists elsewhere in the United Kingdom and abroad. Strong links are being established with the Natural Environment Research Council research institutes and with university groups, notably the Institute of Hydrology, the Institute of Oceanographic Sciences Deacon Laboratory, the Proudman Laboratory, the British Antarctic Survey, the Scott Polar Research Institute, the Robert Hooke Institute, the Climatic Research Unit at the University of East Anglia and researchers participating in the UK Universities' Global Atmospheric Modelling Project. The objective is for the Hadley Centre to become a national facility providing opportunities for scientists, many of whom may be outside the immediate subject area of climate modelling but involved in experimental or physical studies of allied topics, to become involved in the subject through joint research. By this means it is expected that the Centre will be able to draw on expertise covering a very broad range of disciplines.

The present Meteorological Office climate modelling group is recognized internationally to be among the world leaders. The Hadley Centre will welcome visiting scientists; they will be encouraged to work both within the Centre itself and, on a longer term, in co-operation with those at the Centre. One key aspect that will be actively pursued is the intercomparison of climate predictions with those from other Centres in the world; this will provide a measure of the range of uncertainty of the predictions. Another important aim will be to actively encourage the involvement of scientists from developing countries who may lack the availability of large computers and active modelling groups within their own countries, but whose knowledge of their own regions of the world provides useful inputs to the climate modelling problem. By becoming a major centre of excellence on the international stage, with doors visibly open to the participation of others, the Hadley Centre for Climate Prediction and Research will become a lively, active, well respected and influential organization whose advice will be widely sought by those involved in policy formation and implementation.

For further information contact:

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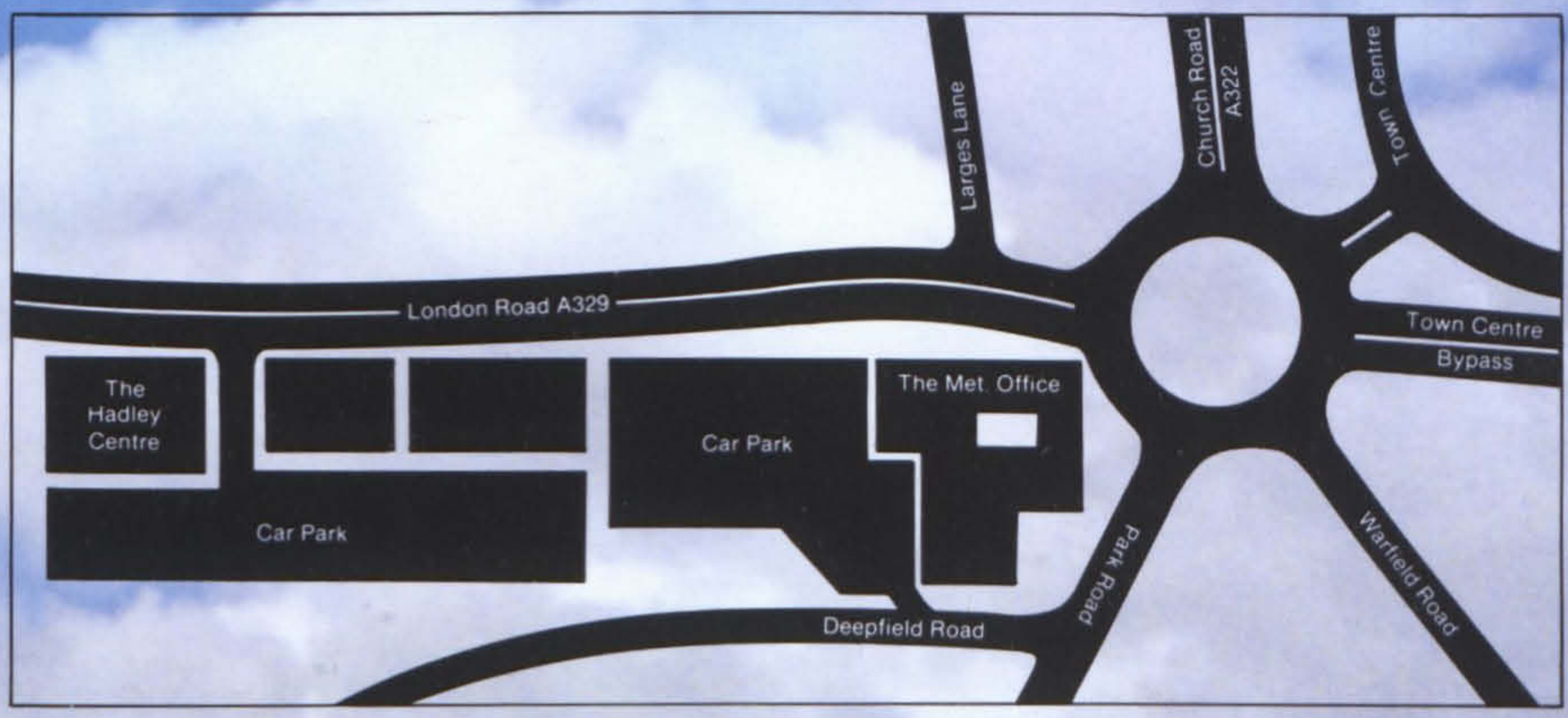

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